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THE RADIATION LABORATORY

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The design of flush mounted (or sensibly flush mounted) antennas for space vehicle applications is a problem of considerable interest at the present time. It is also a difficult problem if a close fit to a specified radiation pattern is desired, and this is particularly true when the requirement is for omnidirectionality. If we assume that the vehicle is some body of revolution, the creation of good fore-and-aft coverage is relatively easy to obtain and requires only an aperture of dimensions small in comparison with the wavelength.

During the past year a variety of problems associated with the realization of specified patterns by sources on curved surfaces have been investigated, with particular reference to omni-directionality, and the following is a brief review of the studies carried out so far.

Consider an infinitely long circular cylinder of radius a at the surface of which the longitudinal component of the electric field is $A(\theta)$. The radiated (voltage and phase) polar diagram (coefficient of

$$\sqrt{\frac{2}{\pi kr}}\, e^{i(kr-\pi/4)}$$

in the far field) is then

$$P(\theta) = \frac{1}{2\pi} \sum_{n=-\infty}^{\infty} \frac{(-i)^n}{H_n(ka)} \int_{-\pi}^{\pi} A(\theta) e^{-in\theta} d\theta \quad , \tag{1}$$

and thus the Fourier coefficients in the far zone are trivially related to those on the surface. In particular, a complete specification of the far field in phase and amplitude determines the surface field uniquely, and vice versa, though we note in passing that the power polar diagram does not provide a unique specification. The conditions on the Fourier coefficients a_n of the surface field obtained from a knowledge of the power polar diagram alone have been investigated.

In almost all practical cases, only a portion of the circumference $-\pi < \theta \leq \pi$ is available for the excitation of the field, and if $A(\theta)$ is required to be zero outside of some aperture $[-\beta_1, \beta_2]$ where $|\beta_1|$, $|\beta_2| < \pi$ the radiated fields that can be reproduced are correspondingly restricted. For a single line source or slot in an infinite plane the work of Rhodes (Trans. IEEE-PTGAP, AP-11, pp 440-446, 1963) provides a completely general method for obtaining a best fit to a chosen polar diagram subject to a pre-assigned value of the superdirective ratio. For a slot on a cylindrical surface an analogous treatment would involve functions which are complete and orthogonal over two finite ranges (c.f. the finite and infinite ranges inherent in the planar problem), and such functions are not available. Moreover, the analogy with the complex angles of radiation which, for a plane slot, are usually regarded as the repository of the reactive power, is not readily apparent.

An alternative approach is to use the geometrical theory of diffraction to determine the radiated field of a slot on a circular cylinder. This is equivalent to applying a Watson transformation to equation (1) with the range of integration restricted to the slot aperture, and retaining only the optics and dominant creeping wave contributions. The analysis has been carried out for a large cylinder ($ka >> 1$) of arbitrary but constant surface impedance (Memorandum 5780-502-M). Since the aperture distribution is a function of the radiation angle θ as well as the position within the slot, direct application of Rhodes' technique is still not possible, but for the radiation pattern in the illuminated half-space a sequential method of optimization was arrived at which is well suited to computation.

A variety of other optimization procedures for one or more slots have been analyzed, including a study of the relationship between 'errors' in the far and near field patterns.

As the number of slots increases, so do the practical difficulties of fabrication, tolerances and feeding. To achieve a sensibly uniform coverage other than with a multitude of slots, various schemes for providing a distributed excitation have been examined. Consider, for example, a horn or antenna on the surface which is so designed as to maximize the excitation of the dominant creeping wave mode. This offers hope of providing tolerable uniformity if the power radiated per unit angle could be reduced to a sufficiently low value. The minimum attenuation of this mode as a function of ka and Z, where Z is the surface impedance of the cylinder, was therefore determined (Memoranda 5780-504 and 505-M), and this in turn led (as by-products) to a new analysis of scattering from a coated cylinder (submitted in November 1963 for publication in the Canadian Journal of Physics) and a further one for scattering from a coated sphere (submitted to Alta Frequenza in May 1964). Although the minimum attenuation was too large to be of practical interest, it did suggest that if the energy lost by the wave through radiation could be replenished, at least in part, a practical device for achieving omni-directionality might result.

Several methods of replenishing the energy were investigated and of these the most promising was a circumferential wire fed from within the cylinder. The effects of wire diameter, coating and height above the surface (including tapered heights) were examined experimentally and the results are reasonably encouraging. The study is continuing.

The possibility of obtaining omni-directionality through the use of a variable refractive index layer within which a source is placed has also been considered, and an initial analysis of the problem led to two papers dealing with dielectric lenses. The first of these was submitted to the Canadian Journal of Physics on 1 June 1964 and the second has been offered for presentation at the URSI-IEEE Fall Meeting in Urbana, Illinois this coming October.

In general, the achievement of a desired coverage in the fore-and-aft direction of a space vehicle is neither as important nor as difficult as the realization of a particular azimuthal pattern, but as a contribution to the former problem the effect of a surface 'kink' (such as at the join of a cone and a cylinder) is being analyzed rigorously. A further analysis that was undertaken is a study of the effect of a concave or flared surface on the currents that it can support. For both problems the analyses are nearing completion

T. B. A. Senior

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